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Evaluation of Commercial Fuel Tank Water Absorbers

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Mobility Technology Center Belvoir

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This report describes the laboratory evaluation of three types of commercial fuel tank water absorber cartridges and a limited field test of one type. Evaluation included absorbance effectiveness, possible deleterious effects on the fuel, and design integrity. Results are discussed together with the potential for use by the Army.

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Section 1 Introduction

OBJECTIVE

This report describes the laboratory and limited field evaluation of commercial fuel tank water absorbers.

BACKGROUND

The Army Quartermaster School requested this Center conduct a laboratory evaluation of one type of fuel tank water absorber cartridge. This was prompted by continual field reports of high levels of free water in vehicular and equipment fuel tanks thought to be caused by infestation, condensation or poor housekeeping. The fuel tank water absorber cartridges are intended to be installed within fuel tanks to continuously absorb free water until they become saturated at which point they must be removed and discarded. A tether is used to secure the cartridge and as an aid in removing the unit once saturated. The Quartermaster School had conducted limited testing on Fuel-Dri cartridges. This Center included two other manufacturers in this evaluation to eliminate any potential for bias and to encourage competition.

Section 2 Investigation

TEST ITEMS

The three test items are described below based on manufacturers' literature and observations. Salient features are shown in Table I.

Sta-Dri

Sta-Dri is manufactured by Polysorb Inc. It is available in six sizes for different capacity fuel tanks. It consists of a bag made of rip-stop parachute fabric containing a starch grafted polymer as an absorbent and silica sand as a ballast. A relatively short nylon tether is used terminating in an alligator clip. The nylon tether is intertwined with fine wire perhaps for additional strength or grounding purposes.

Water Eliminator

Manufactured by American Transportation Technology, the Water Eliminator comes in one size only. It consists of a cylindrical cage of molded nylon ribbing surrounded by an open mesh screen. Inside the cage is the absorbent, polyacrylamide crystals, a form of synthetic starch. Ballast is provided by a length of lead wire. A relatively short nylon tether terminates with a snap closure. Subsequent to this evaluation, the manufacturer indicated that they could market a version using a stainless steel cable tether with snap closures at each end. The manufacturer's literature states that the Water Eliminator should lie flat in bottom of the fuel tank.

Fuel-Dri

This is manufactured by Dewatering Systems International. It comes in three different sizes to cover both vehicle tanks as well as storage tanks. It consists of two separate components. A rigid reusable cylindrical sleeve is made of a high density polyethylene ventilated on the periphery. Both ends are heavily ballasted with lead weights. The front end is attached to a stainless steel tether terminating in a snap closure with a ball swivel. The tail enclosure opens for access to the absorbent cartridge. The disposable absorbent cartridge, containing the absorbent, is made of open mesh screen of high density polyethylene heat sealed at each end. The absorbent is polyacrylamide crystals. The manufacturer recommends pre-wetting the cartridges with water before use and this procedure was followed in this test.

Table 1. Salient Features of Absorber Cartridges

TEST ITEM	STA-DRI	WATER ELIMINATOR	FUEL-DRI
General Design Features	Disposable flexible porous bag containing absorbent and ballast	Disposable rigid porous plastic cylinder, absorbent in bottom	Reusable rigid porous plastic cylinder with disposable plastic bag in bottom
Size(s) Available	6	1	3
Weight of Absorbent in Test Item (avg.), g	55.17* (w/ballast)	0.66	1.00
Absorbent	Starch grafted polymer	Polyacrylamide crystals	Polyacrylamide crystals
Container Material(s)	Parachute fabric	Molded nylon	High density polyethylene
Ballast	Sand, mixed in with absorbent	Lead weight	Lead weight in closure
Tether	Nylon cord, 140 cm long, with alligator clip at end	Nylon cord, 66 cm long, with spring clip at end	Stainless steel cable, 206 cm long, with Spring clip at end

* Weight includes sand ballast which could not be separated from absorbent.

TEST FUELS

The fuel tank water adsorbent cartridges are intended for ground fuels only. The Army's tactical/combat ground fuels are diesel fuel and the Single Fuel on the Battlefield (generally JP-8). Tests were therefore performed with diesel fuel No. 2 (DF-2) meeting the requirements of VV-F-800 and JP-8 meeting the requirements of MIL-T-83133.

APPROACH

Laboratory Evaluation

The laboratory evaluation tested representative samples of each type of absorber cartridge to determine absorbance effectiveness and possible deleterious effects on the JP-8 test fuel. Prior to testing, each of the test absorber cartridges was cut open, the absorbent extracted, weighed and replaced and the cartridge resealed with fuel/water resistant sealant or stitches.

Each of the test absorber cartridges was exposed to separate batches of DF-2 and JP-8 fuel, both dry and containing free (i.e., separated) water in a simulated fuel tank environment. In addition, each test utilized two batches of JP-8, one dry and one with free water, not used for absorber tests but kept as controls. The test JP-8 was analyzed for additive levels (Corrosion Inhibitor, Fuel System Icing Inhibitor and Static Dissipator Additive) prior to the test, the analysis data is reflected in the dry JP-8 control test results. Five rectangular aluminum containers of approximately 30 liters (8 gallons) capacity each were used to simulate fuel tanks. Each container was filled with exactly 15 liters of test fuel. Three liters of distilled water was added to those container used in free water test. The water level was sufficient to insure that the cartridges were completely submerged in the water layer. The candidate cartridges were immersed in the container for four hours, moderate agitation was accomplished by rocking the container for five minutes every hour. At the conclusion of this period, the cartridges were removed and the remaining volumes of fuel and water in the container were carefully measured. The amount of fuel or water absorbed was based on the changes in volume of the water and fuel left in the container. The JP-8 fuel was re-analyzed for additive levels after exposure to water and to the absorber cartridges. These values were compared to the controls not exposed to the absorber cartridges.

Ruggedness and Design Integrity

Each test sample cartridge was examined visually to determine design factors that would limit its use in Army equipment.

Field test

This test was conducted only with Fuel-Dri. Three cartridges were installed in a Bradley Fighting Vehicle (BFV E 31) assigned to the 3/41st Infantry at Ft. Hood, TX. The cartridges remained in the BFV for approximately seven months (30 September 1993 through 20 April 1994) and were subjected to repeated refuelings with JP-8.

RESULTS

Laboratory Evaluation

Results of absorbance and fuel effects tests are given in Tables II through VII. Included are post-test analysis of test JP-8 for additive depletion compared with control batches of JP-8 both dry and water laden.

Table 2. Results from Sta-Dri Absorber Cartridges Immersed in DF-2

	DF-2, DRY	DF-2, WATER LADEN
Fuel absorbed, mL	nil	N/A
Water absorbed, mL	N/A	283
Water absorbed, mL/g absorbent	N/A	4.7

Table 3. Results from Sta-Dri Absorber Cartridges Immersed in JP-8

POST-TEST FUEL ANALYSIS COMPARED WITH CONTROL JP-8 WITHOUT CARTRIDGES

	JP-8, DRY	JP-8, WATER LADEN	CONTROL JP-8, DRY	CONTROL JP-8, WATER LADEN
Fuel absorbed, mL	nil	N/A		
Water absorbed, mL	N/A	101		
Water absorbed, mL/g absorbent	N/A	2.2		
Level of FSII, %	0.11	0.01	0.14	0.01
Fuel conductivity, pS/m	20	24	23	24
Level of corrosion inhibitor, g/m^3	6.14	4.17	9.19	4.93

Table 4. Results of Water Eliminator Absorber Cartridges Immersed in DF-2

	DF-2, DRY	DF-2, WATER LADEN
Fuel absorbed, mL	nil	N/A
Water absorbed, mL	N/A	110
Water absorbed, mL/g absorbent	N/A	169.2

Table 5. Results from Water Eliminator Absorber Cartridges Immersed in JP-8

POST-TEST FUEL ANALYSIS COMPARED WITH CONTROL JP-8 WITHOUT CARTRIDGES

	JP-8, DRY	JP-8, WATER LADEN	CONTROL JP-8, DRY	CONTROL JP-8, WATER LADEN
Fuel absorbed, mL	nil	N/A		
Water absorbed, mL	N/A	62		
Water absorbed, mL/g absorbent	N/A	93.2		
Level of FSII, %	0.13	0.01	0.13	0.01
Fuel conductivity, pS/m	26	31	28	30
Level of corrosion Inhibitor, g/m^3	7.4	5.69	6.47	5.01

Table 6. Results from Fuel-Dri Absorber Cartridges Immersed in DF-2

	DF-2, DRY	DF-2, WATER LADEN
Fuel absorbed, mL	nil	N/A
Water absorbed, mL	N/A	105
Water absorbed, mL/g absorbent	N/A	104.9

Table 7. Results from Fuel-Dri Absorber Cartridges Immersed in JP-8

POST- TEST FUEL ANALYSIS COMPARED WITH CONTROL JP-8 WITHOUT CARTRIDGES

	JP-8, DRY	JP-8, WATER LADEN	CONTROL JP-8, DRY	CONTROL JP-8, WATER LADEN
Fuel absorbed, mL	nil	N/A		
Water absorbed, mL	N/A	97		
Water absorbed, mL/g absorbent	N/A	96.9		
Level of FSII, %	0.16	0.01	0.19	<0.01
Fuel conductivity, pS/m	60	32	26	32
Level of corrosion inhibitor, g/m^3	12.48	5.76	8.51	8.30

Table 8. Summary of Water Absorbance Results After Immersion in Water Laden DF-2 and JP-8

	WATER ABSORBED, mL/g ABSORBENT, AFTER IMMERSION IN WATER LADEN DF-2	WATER ABSORBED, mL/g ABSORBENT, AFTER IMMERSION IN WATER LADEN JP-8
Sta-Dri	4.7	2.2
Water Eliminator	169.2	93.2
Fuel-Dri	104.9	96.9

Ruggedness and Design Integrity

Samples of each type of absorber cartridge were examined to determine design integrity for possible usability in Army equipment.

Sta-Dri. This design possesses serious limitations. It does not utilize a rigid outer shell but is simply a bag filled with absorbent and sand. This means that it can expand after contact with water possibly to the point where it could not be removed through the fuel inlet. The sand ballast is, in many cases, inadequate as some of the units tended to float in fuel and water; some would not lie flat in the tank but would sit vertically. In case of rupture of the bag, the sand could get into the fuel. In addition the nylon tether tends to unravel and its attachment to the bag is only by means of a simple knot.

Water Eliminator. This cartridge is well designed and would probably hold up well under all circumstances. The rigid outer shell prevents any expansion. However the nylon tether does not seem strong enough to resist deterioration under continuous contact with fuel. The tether is long enough for vehicular or equipment fuel tanks but may be too short for some storage tanks. The lead ballast is compatible with the fuel but the unit is slow to sink in fuel or water due to some air entrapment behind the screen.

Fuel-Dri. The use of a rigid reusable sleeve with a disposable absorber cartridge would seem to be cost effective but it would require an additional National Stock Number. The sleeve appears slightly less well made than the Water Eliminator which may have some effect under rough handling. The Fuel-Dri unit had no problems with floating in fuel or water. When the units are new, it is easy to open the sleeve closure to access the absorbent. However, after they are exposed to fuel and aged, the closure tends to stick and require pliers to open. The stainless steel tether is very strong and is a definite positive factor.

Field test

The three Fuel-Dri cartridges were removed from the BFV in the presence of personnel from the PM-BFV office, a United Defense Field Service Representative (FSR), and a representative of the Mobility Technology Center-Belvoir. The cartridges were examined for degradation or damage. Details of this examination are given in a separate trip report (Reference 3). The internal bags of all three cartridges had swelled to the same degree indicating that they had seen the same quantity of fuel. The absorbent had darkened considerably which was not expected after exposure to the water white JP-8. Two of the three cartridges had their top closure come off while in the fuel tank; the other cartridge remained intact. However, all three cartridges experienced problems with absorbent penetrating through the inner bags without actually causing rupture. In the case of the two cartridges with missing closures this resulted in the crystalline absorbent getting into the fuel tank. The effect of absorbent crystals loose in the fuel tank could not be determined. It was assumed that the cartridges were fully saturated, i.e., had absorbed all the water for which they are capable. However, when placed in a container of water they absorbed approximately 570 mL of additional water. This despite the fact that there was still water left in the fuel tanks in an emulsified state.

Section 3 Discussion and Conclusions

DISCUSSION

a. All of the test absorber cartridges absorbed water and did not absorb fuel. The effectiveness of the absorbance is measured by the test parameter labeled "WATER ABSORBED, mL/g ABSORBENT" summarized in Table 8. Unfortunately, the Sta-Dri unit had the ballast sand mixed in with the absorbent so that there was no way to determine the real weight of the absorbent. For the other two,: the Water Eliminator was somewhat more effective in removing water from fuel in DF-2 than Fuel-Dri but the two were about equal when used with JP-8. No explanation can be given why all units were more effective in removing separated water from DF-2 than from JP-8 (especially Sta-Dri) except for the fact that the water layer below JP-8 will contain Fuel System Icing Inhibitor (FSII).

b. There was no evidence that the absorber cartridges degraded the fuel from the limited testing that was performed. Fuel that had been contacted with water indicated substantially lower levels of Fuel System Icing Inhibitor (FSII) but this is to be expected as the FSII is water and well as fuel soluble. Variations of the level of corrosion inhibitor is within the experimental error of the test method and may have something to do with the presence of water. Compared with the controls the difference is not significant. The increase in fuel conductivity shown with Fuel-Dri in dry JP-8 had been experienced previously in vendor's tests conducted elsewhere. The difference may be statistically significant but as long as the fuel is not to be used in aircraft it should have no real physical effect.

c. The only real significant difference in the three test absorber cartridges is in their design integrity or "ruggedness". The Sta-Dri has to be considered unacceptable because of its lack of a rigid outer shell, its use of a fabric bag that can swell and possibly rupture, its tether material, the method of attachment of the tether to the cartridge, its tendency to sometimes float, and its use as of sand as a ballast. The Water Eliminator is sufficiently rugged and would be fully acceptable if a stronger tether could be incorporated. Fuel-Dri was found to be the best overall design principally due to its use of a stainless steel tether although some improvement in construction of the sleeve may be warranted.

d. The limited field test of Fuel-Dri indicated potential user problems for long term use.

CONCLUSIONS

a. The Fuel-Dri absorber cartridge was found to be effective, non-harmful to fuel, and rugged enough for Army use. The Water Eliminator could be acceptable if a stainless steel tether could be incorporated into its design.

b. This test did not address long term use, compatibility with military vehicles and ground equipment, cost effectiveness, acceptability to the user community (soldiers) or environmental problems. These issues may be addressed in subsequent test programs.

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